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Abstract—*The* ***K*ON*V*E*R*GENCE** ***Model for Sustainable Decisions*** *is a new way of viewing, developing, organizing, and evaluating alternatives for decisions that may affect a wide range of interests and that must factor in long timeframes, enduring hazards, and/or continuing responsibilities. It differs from other models in that it addresses the need for decisions to continue to "work" over long time periods in an ever-changing decision environment. The authors show that the model contains three major universes—****knowledge****,* ***values****, and* ***resources*** *(the K, V, and R in* KON*V*ERGENCE*)—that interact and overlap throughout the effective lifetime of a decision. They discuss how decision-makers and decision participants can use the model to craft and analyze decisions and decision processes that stand the test of time. The authors use the U.S. moon-landing program as an example of a major decision process that was sustained over time. They use the model to explain why events unfolded in the way that they did—and why we are where we are today in that program. The authors believe that this model will be especially useful in long-term decision processes such as those that address contamination cleanup programs, long-term environmental stewardship, and the initial siting of facilities with long-term objectives. Companion papers describe* the *KON*V*ER*GENCE *Model process steps*[1] *and implications for intractable cleanup decisions.*[2]

I. INTRODUCTION

The ***K*ON*V*E*R*GENCE Model for Sustainable Decisions** is a new way of viewing, developing, organizing, and evaluating alternatives for decisions with long timeframes, enduring hazards, and/or continuing responsibilities. It differs from other approaches in that it addresses the need for decisions to continue to "work" over long time periods in an ever-changing decision environment.[3]

We offer these ideas to solicit feedback and continue progress. This philosophical model was developed during the first half of a three-year research project with the goal of improving decision-making for decommissioning-stewardship-waste management. Readers may find it helpful to first read the companion framework and process paper[1] and lastly the paper on implications for intractable cleanup problems.[2] Although developed for cleanup decisions, the *K*ON*V*ER*G*ENCE Model appears useful for a far broader set of decisions. During the second half of our project, we will continue to refine and test our concepts. This is a research project and does not represent official positions of the Department of Energy or its contractors.

II. THE MODEL'S "UNIVERSES"

The model reflects that decisions about alternatives require three major factors over time: ***Knowledge***, ***Values***, and ***Resources***. In the model, each of these factors is called a "universe" and will be "mapped" onto an ***alternatives*** universe. The alternatives universe contains all of the imaginable alternatives (i.e., decision points). ***Imagination***, therefore, drives the boundary of the universe of alternatives.

The ***knowledge*** universe consists of all of what is technologically and factually known or can currently be ascertained about the situation. In the model, populating the ***knowledge*** universe is called ***investigation***. It includes gathering data and information as well as analyzing and interpreting data and information. It also includes data and information that can be derived from various analytical techniques (e.g., risk analyses, performance assessment), but such materials must be carefully considered for inherent assumptions and

extrapolations. ***Investigation***, therefore, drives the boundary of the universe of ***knowledge***.

The ***values*** universe includes what is important to everyone affected by a decision, starting with higher-level values down to detailed objectives and performance measures relevant to each decision.[1] Each decision must incorporate the ***values*** of the participants in *and* those that may be affected by a decision. The key to getting a complete representation of ***values*** for a given decision is ***participation*** by those affected. ***Participation***, therefore, drives the boundary of the universe of ***values*** and also figures prominently in the development of imaginative alternatives.

The ***resources*** universe consists of the ***resources*** that society can bring to bear on the problem. ***Resources*** in the model include natural resources (land, minerals, water, etc.), financial resources, trained personnel, supporting infrastructure (e.g., availability of waste disposition sites, supporting industrial capabilities, transportation systems, etc.), and time. ***Resources***, by their very nature, are scarce. ***Availability***, therefore, drives the boundary of the universe of ***resources***.

III. THE "*KONVERGENCE*"

The area where the universes overlap or "converge" is called the ***konvergence***. The *konver*gence is the area in which sufficient and appropriate ***knowledge*** about the alternatives is available, the common ***values*** of the participants are reflected, and sufficient ***resources*** to implement the alternatives are available. Anywhere within the *konver*gence, an effective decision on the alternatives can be made (Figure 1).

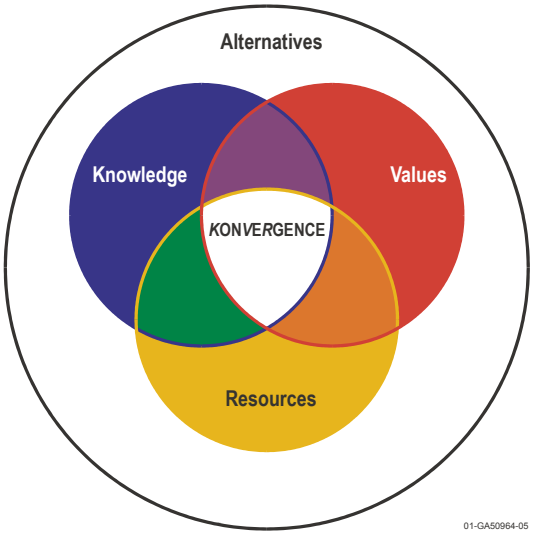

Figure 1. The *KONVERGENCE* Model for Sustainable Decisions

Knowledge, ***values***, and ***resources***, however, are all dynamic so it can be said with certainty that the *konver*gence will expand and contract non-uniformly and continually (or may even disappear altogether) over time.

- ***Knowledge*** generally increases with time. The major *threat* is that assumptions and extrapolations may prove to be wrong. New data may show an implemented decision is not working adequately. A formerly acceptable decision may then no longer be acceptable. Examples of major *opportunities* that may increase the *konver*gence would be the demonstration of a new technology or a definitive mitigation technique for a particular hazard.
- ***Values*** change with time because participants' ***values*** may evolve with time or because of new participants whose ***values*** were not considered in the initial decision. If trends over the past few decades hold, we could expect that risk levels considered acceptable today may not be considered acceptable in the future, thereby reducing the *konver*gence. This could be considered a *threat* to a particular decision point. It could also be argued that due to other pressing societal or environmental concerns (e.g., global warming, increasing population, decreasing bio-diversity, water shortages) the opposite could occur—which would be an o*pportunity* increasing the *konver*gence. Other opportunities for increasing the *konver*gence include increased participation, education, and genuine dialog to identify and explore a wider range of common ***values***.
- ***Resources*** change with time for several reasons. For example, *threats* include loss of trained personnel, exhausting a rare/irreplaceable natural resource, lack of time to implement a decision, or cost overruns. New *opportunities* may arise by finding alternative resources, by finding ways to use existing resources more efficiently, or by eliminating the use of a particular resource. Societal wealth will also generally increase over time. Or, decisions that were thought to be fixed or irreversible because of resource limitations may become more adaptable or even reversible (e.g., a low cost way to accurately characterize and safely exhume waste).

IV. SIGNIFICANCE OF OTHER PARTS OF THE MODEL—"PETALS" AND "FANS"

Although theoretically there is a potential *konver*gence where all three universes overlap perfectly, in practice this will never be the case. The three universes, at best, will only partially overlap to form the *konver*gence. But other parts of the model are equally as important as the *konver*gence.

The "**petals**" that surround the *k*on*ver*gence represent three distinct areas where there is an overlap of two universes (Figure 2). These petals represent important constraints on the *k*on*ver*gence that, if addressed, may increase the size of the *k*on*ver*gence.

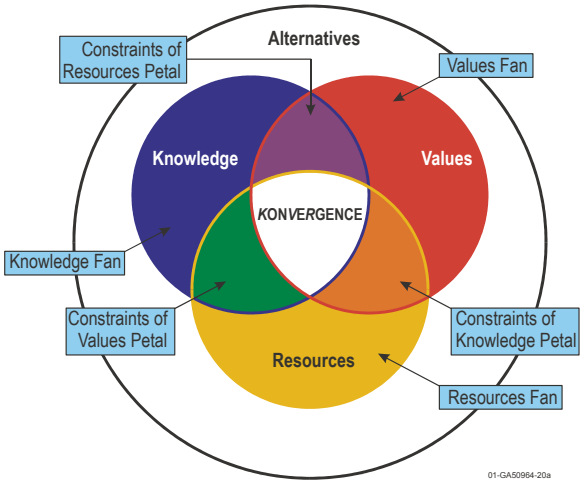

Figure 2. The *k*on*ver*gence "petals" and "fans"

The petal labeled "**Constraints of Knowledge**" is an area where ***resources*** exist and the participants' ***values*** are included, but where we do not have sufficient ***knowledge***. For example, the technical know-how is insufficient, a new technology needs to be developed, or the appropriate ***knowledge*** has not yet been gathered and analyzed. This petal is an area where traditional scientific/technical research and development or information/data gathering may be fruitful.

Likewise, the petal labeled "**Constraints of Values**" is an area where sufficient and appropriate ***knowledge*** exists and there are ***resources***. However, for some reason the participants' ***values*** do not encompass this area. It could be, for example, that those alternatives are not politically or socially acceptable. This petal is an area that may require additional participation/communication tools, education, political activism, etc.

The petal labeled "**Constraints of Resources**" includes the area where we have appropriate and sufficient ***knowledge*** and the ***values*** of the participants are considered, but ***resources*** either do not exist or are insufficient. The constraint could be on trained personnel, for example, or a lack of financial resources or manufacturing capabilities. This petal is an area where there is potential for exploring solutions such as alternative funding mechanisms, technical training, or resource substitution.

The value of the petals is that they point the way to potential solutions (that are not currently within the *k*on*ver*gence) with a higher probability of success since they have two of the three required universes. The petals offer insights into action/research directions and priorities. For instance, it would be futile and a waste of resources to pursue additional research and development of new technologies (i.e., applying efforts in the **constraints of knowledge** petal to increase ***knowledge***) when the problem lies in a clash of ***values*** (the **constraints of values** petal).[4]

The areas of the three universes that surround the *k*on*ver*gence, but do not overlap with one of the other universes are called the "**fans**" (Figure 2). The fans represent an area where factors in only one of the three universes are present. To achieve *k*on*ver*gence in these areas would require the boundaries of the other two universes to move. While not impossible, it would appear to be less likely to achieve *k*on*ver*gence for decision points in the fans than for those in the petals. Still, given specific circumstances, it may be worthwhile to try.

V. HOW THE MODEL INCORPORATES LAWS, REGULATIONS, AND OTHER REQUIREMENTS

Laws, regulations, ordinances, orders, procedures, etc. are requirements of various levels of government or other authorities. They do not comprise a universe in and of themselves; rather, they are primarily an incomplete and imperfect representation of society's ***values*** (given contemporary ***knowledge*** and ***resources***) at a specific point in time. They will never perfectly overlap the participants' ***values*** universe. In that sense, the model represents them as an additional important factor that must be considered with the ***values*** universe (Figure 3).

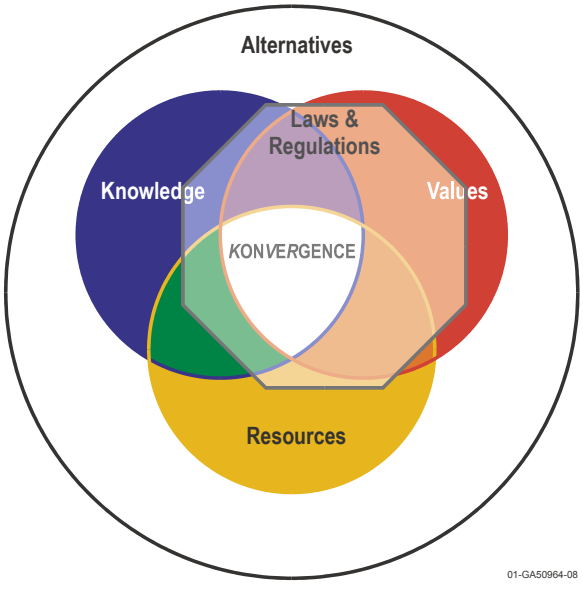

Figure 3. Laws and regulations are an "overlap" of the *values* universe

Laws and regulations can be "out of sync" with the ***values*** universe in two opposite directions with respect to the *konvergence*. These situations demand two completely different responses when trying to ensure that decision points within the *konvergence* also satisfy laws and regulations (and vice versa) that are out of sync with the ***values*** universe.

The first situation is when the decision point lies within the laws and regulations area that overlaps the ***knowledge*** and ***resources*** universes (the **constraints of values** petal), but falls outside of the ***values*** universe. In this case, it represents a situation where additional requirements, called **derived requirements** by Fawcett et al.,[5] are needed. Derived requirements will need to be solicited, developed, and quantified for the decision point to reflect the ***values*** of the participants and therefore move from the **constraints of values** petal to lie within the *konvergence* (Figure 4).

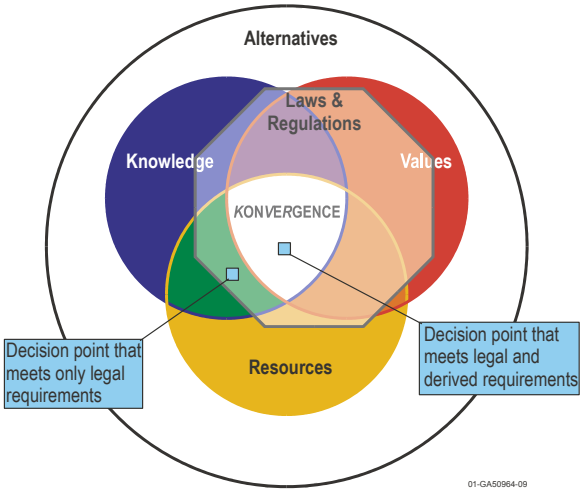

Figure 4. Derived requirements may be necessary in addition to meeting laws and regulations in order to gain *konvergence*

The second situation is when the legal requirements are out of sync with the ***values*** universe in the opposite direction (i.e., the decision point is within the *konvergence*, but is not within the legal requirements area). In this case, it will be necessary to seek a change in the law or regulation or an exemption to it (Figure 5).

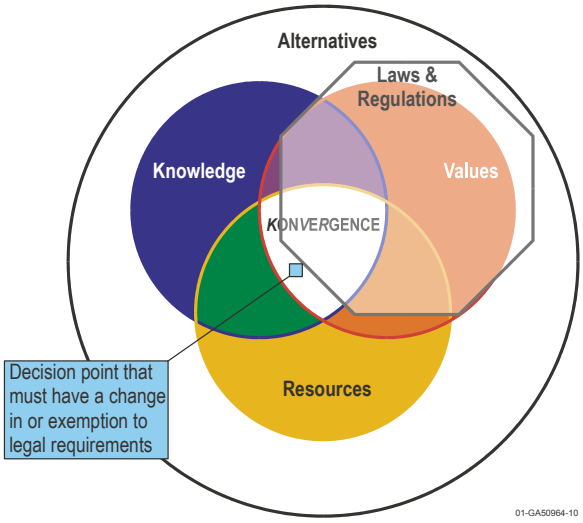

Figure 5. A change or exemption to laws or regulations may be necessary to gain *konvergence*

VI. IMPLICATIONS OF A CHANGING *KONVERGENCE* ON DECISION-MAKING

For a decision to remain effective over time, it must remain *at all times* within a changing *konvergence*. The "oscillation" of the *konvergence* becomes especially important in decisions that address long timeframes or enduring hazards.

- "Staged" decision processes offer opportunities to move with the ebb and flow of the *konvergence* (Figure 6). Contingencies are built into the decision process. What some may consider a disadvantage, however, is a continuing duty to periodically reevaluate past decisions (i.e., the *rolling present* or *rolling stewardship* concept).

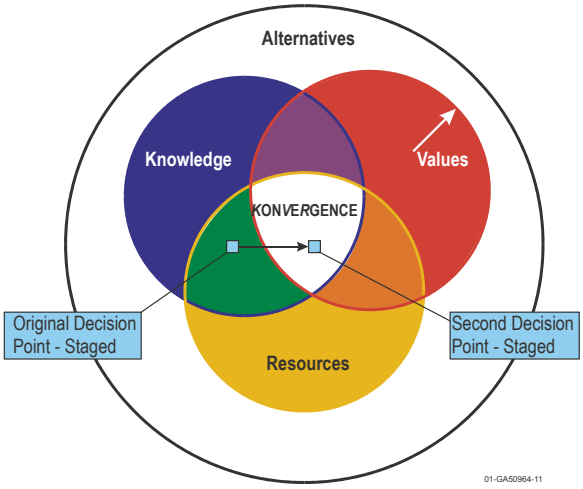

Figure 6. Staged decision points

- An "end-state" decision point is an immovable point that, by definition, cannot react to changes in ***knowledge***, ***values***, or ***resources*** (Figure 7). Although such decisions can be made and can continue to be effective, there is a risk that the fixed point may at some time fall outside of the *k*on*ver*gence. Should that occur, the decision *may* be "unmade" (recognizing that there will likely be a certain inertia or "threshold of reversal" to cross where the pain of reversal is less than the pain of letting the decision stand).

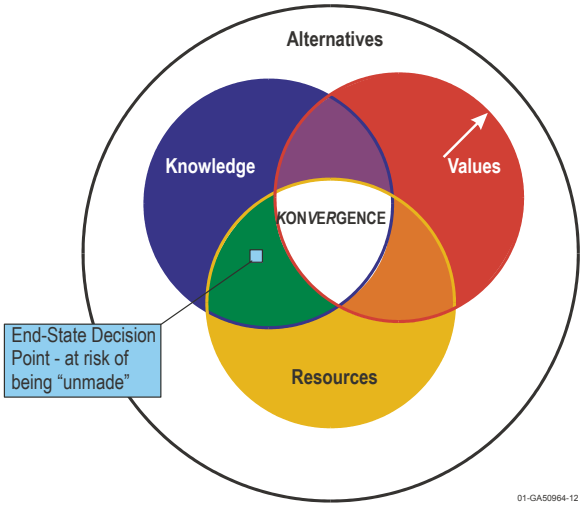

Figure 7. An "end-state" decision point

VII. CAN THE *K*ON*VER*GENCE BE MANAGED?

To this point, we have shown that modifying decision points to move with the *k*on*ver*gence oscillations is one valuable method to manage decisions over time. But can we not also move the boundaries of the universes and "manage" the *k*on*ver*gence? Obviously, the *k*on*ver*gence cannot be managed in the sense of absolutely controlling its movements. There are too many forces that determine its extent and movement. But decision-makers *can* and *must* manage it in the sense of exerting a positive influence on it, anticipating changes in it, and managing their actions and reactions with respect to changes in it. Decision-makers must discern how the *k*on*ver*gence is changing and decide to act on that basis. Blending these two strategies—modifying decision points and positively influencing the *k*on*ver*gence boundaries through leadership can be an effective management approach (Figure 8). To do this, decision-makers must:

- Assess the extent of each universe to determine the boundaries. This step will in fact be the most difficult activity to accomplish. To discern what is in the ***knowledge*** universe will require dispassionate appraisal of the state of the art science and technology; critical examination of all assumptions and extrapolations; and accurate and complete data gathering and analysis. To assess the ***values*** universe will require extensive identification of stakeholders and their effective participation throughout the process. To establish the boundaries of the ***resources*** universe will require a thorough inventory of available funds, skills, infrastructure, etc. Decision-makers must work to reduce the inherent uncertainties and must keep assumptions and extrapolations to a necessary minimum. Only when the three universes have been sufficiently defined will the *k*on*ver*gence be evident and accurate.
- Identify laws, regulations, ordinances, and other requirements to determine the overlap with the ***values*** universe. Working with the participants, identify any needed derived requirements or changes in laws, regulations, etc. to ensure that decision alternatives will lie within the *k*on*ver*gence.
- "Map" the decision points on the model diagram. Once the universes are known, decision points can be mapped onto the diagram. With full participation, it should be relatively easy to assign decision points to specific parts of the model; however, this step will involve some subjectivity.
- Monitor the three universes to determine trends/changes in the extent of boundaries and their direction of movement over time. Because of the long time periods contemplated, this must be done at least periodically to determine if decision points continue to reside in the *k*on*ver*gence. Decision-makers may be able to see a trend in the movement of the boundaries and anticipate changes or design contingency plans. This step and the next should be those in which uncertainties, assumptions, and extrapolations are reduced over time.
- Make efforts to address shortcomings of decision points within the petals or fans. If current or future decision points lie outside of the *k*on*ver*gence, but in one of the petals or fans, then it may be effective to undertake efforts aimed at moving or better defining the boundaries. For example, if a decision point lies in the **constraints of knowledge** petal, it may be worthwhile to design a research and development project targeted to gain the ***knowledge*** necessary for the decision point to fall within the *k*on*ver*gence.

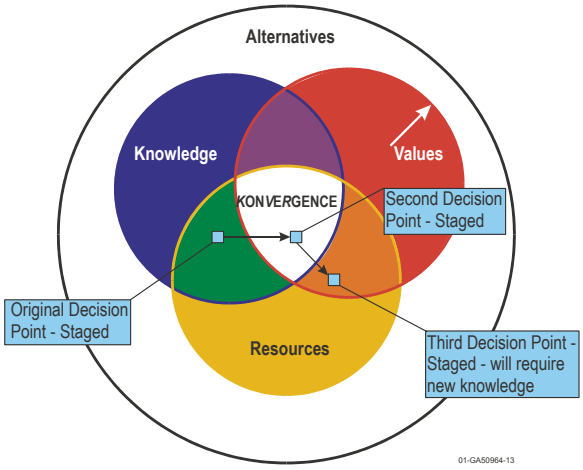

Figure 8. "Managing" the *konvergence*

VIII. "WE CHOOSE TO GO TO THE MOON…"

As an example of how the *konvergence* changes over time and how to some extent it can be managed, we can look at past decision processes that have been sustained over time. One of the most famous examples of a long-range vision that triggered a complex series of successful decisions over time is the challenge to land a human being on the moon. This project involved "managing," albeit unknowingly in some cases, the boundaries of the universes to create a *konvergence* so that as a nation we could accomplish an important task.

On May 25, 1961, President John F. Kennedy delivered the "Special Message to the Congress on Urgent National Needs." In this message, he posed a daunting challenge to the nation: "…I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth." Interestingly, when we look at this message through the lens of the ***KONVERGENCE* Model for Sustainable Decisions** (and with hindsight), it is almost uncanny how Kennedy displayed at least an intuitive grasp of what needed to be done in order to gain *konvergence*, which was clearly lacking at the time. He even went so far as to preface his challenge with references to factors in all three of the universes.

First, with regards to the ***resources*** universe, he stated, "I believe we possess all the resources and talents necessary. But the facts of the matter are that we have never made the national decisions or marshaled the national resources required for such leadership. We have never specified long-range goals on an urgent time schedule, or managed our resources and our time so as to insure their fulfillment." He accurately surmised the decision point was somewhere within the ***resources*** universe.

Second, he apparently recognized that the decision point was not yet within the ***values*** universe. He made statements aimed at moving the boundary of the ***values*** universe: "If we are to win the battle that is now going on around the world between freedom and tyranny, the dramatic achievements in space which occurred in recent weeks [Alan Shephard's first American space flight] should have made clear to us all, as did Sputnik in 1957, the impact of this adventure on the minds of men everywhere, who are attempting to make a determination of which road they should take. …Now it is time to take longer strides—time for a great new American enterprise—time for this nation to take a clearly leading role in space achievement, which in many ways may hold the key to our future on Earth." By requesting additional funds, he recognized that our priorities, which are a manifestation of our ***values***, were not yet in place.

Third, he stated unequivocally that our ***knowledge*** was as yet insufficient to meet the challenge: "This decision demands a major national commitment of scientific and technical manpower, material and facilities…it means a degree of dedication, organization and discipline which have not always characterized our research and development efforts."

In summary then, he accurately recognized that the decision point was in the fan of the ***resources*** universe and he further recognized that the boundaries of the ***values*** universe *and* the ***knowledge*** universe needed to move—a daunting prospect—before a moon landing could be accomplished (Figure 9).

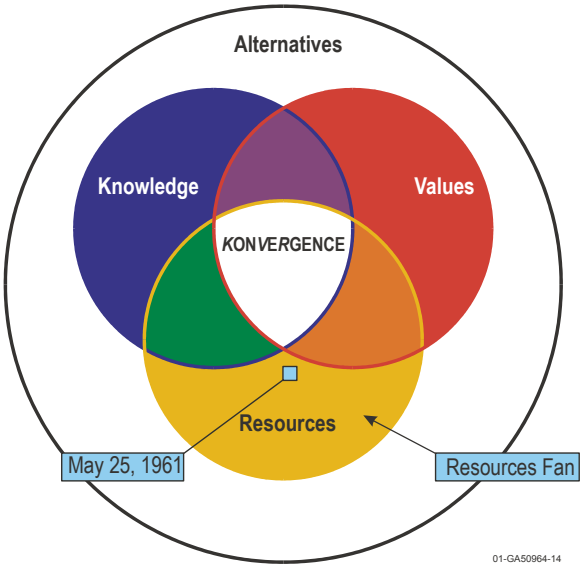

Figure 9. Kennedy needed to positively influence the *values* and *knowledge* universes in his speech on May 25, 1961

On September 12, 1962, President Kennedy made a speech at Rice University in Houston, Texas. By this time, Congress had appropriated large sums of money for the space program, John Glenn had orbited the Earth, many satellites with "Made in the U.S.A." on them had been launched, and public opinion had clearly shifted in favor of continuing the efforts in space. Kennedy recognized that the boundary of the ***values*** universe had moved over the intervening sixteen months. Instead of his wording of the 1961 Special Message to Congress "…*I believe* that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth…" he said, "*We choose* to go to the moon. *We choose* to go to the moon in this decade and do the other things, not only because they are easy, but because they are hard…" [emphasis added]. With these statements, he apparently recognized that the decision point was now in the **constraints of knowledge** petal (Figure 10).

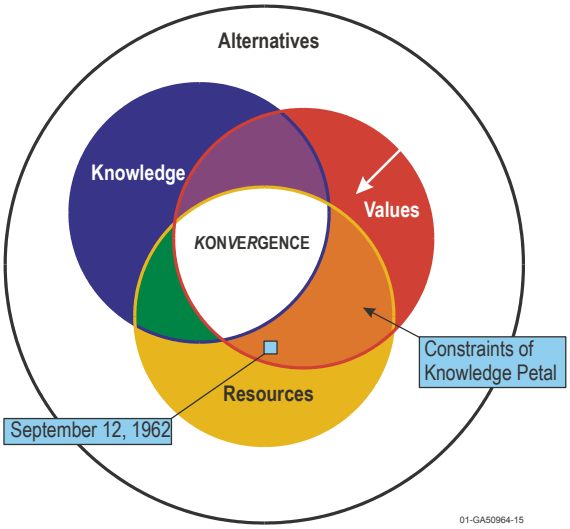

Figure 10. The *values* universe had moved by September 12, 1962, but further *knowledge* was needed

Near the end of the decade of the 1960's, we had successfully completed many manned space flights and tests of the Gemini spacecraft and the Apollo moon spacecraft. The boundary of the ***knowledge*** universe had moved to encompass being capable of landing men on the moon and returning them safely to Earth. On July 20, 1969, we graphically demonstrated that we had *konvergence* by landing men on the moon. We continued to accomplish this feat until December 14, 1972 when Apollo 17 lifted off the moon for the last time (Figure 11).

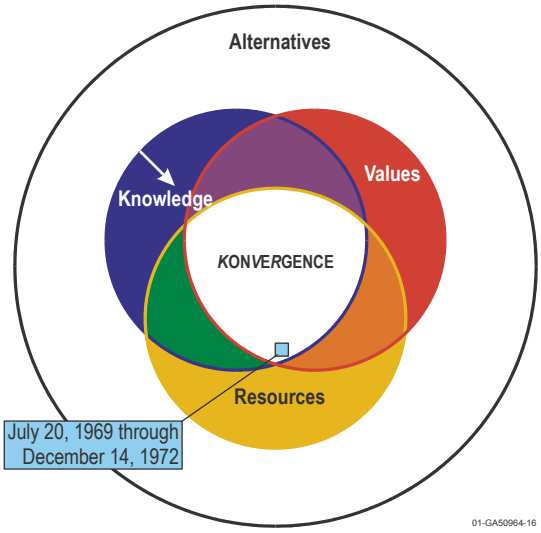

Figure 11. The decision to land humans on the moon was in *konvergence* from July 20, 1969 through December 14, 1972

Since then, our national priorities—a manifestation of our ***values***—have changed; we no longer have *konvergence*. We still have the requisite ***knowledge*** and ***resources*** (i.e., the decision point is in the **constraints of values** petal)—we just choose not to do it (Figure 12).

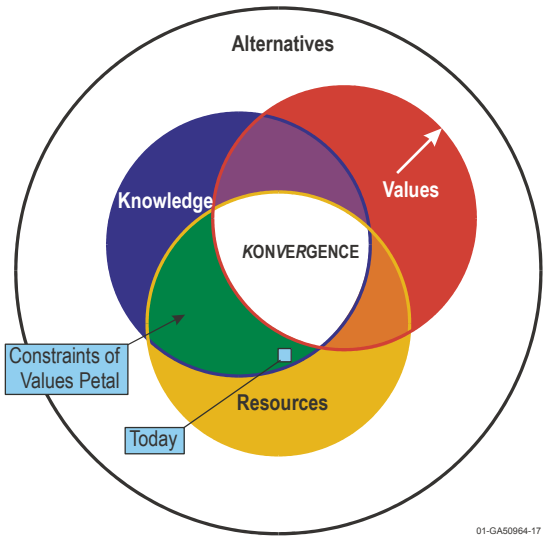

Figure 12. Today, we do not have *konvergence* for sending humans to the moon

IX. CONCLUSION

The foregoing example of the moon program illustrates how the ***KONVERGENCE* Model for Sustainable Decisions** can be used to "map" the

boundaries of the universes and location of decision points over time. It is also a prime example of the strategy of moving the boundaries of universes to encompass important future decision points, which generally takes visionary leadership. ***Naturally gifted decision-makers*** (such as Kennedy) have demonstrated an intuitive understanding of this process and have been successful at it. Without those extraordinary natural gifts *or a repeatable model*, others have been unsuccessful or have stumbled through decision processes. The ***K*ON*V*E*R*GENCE Model for Sustainable Decisions** should be useful to all decision-makers to logically organize the decision process while graphically depicting (and therefore better understanding) the forces and circumstances surrounding decisions. It should, therefore, be a repeatable model. It should also help to manage those factors under their control and discern what factors need to be monitored and/or managed in order to accomplish goals and lead decision processes. In short, the ***K*ON*V*E*R*GENCE Model for Sustainable Decisions** should help decision-makers with their leadership roles in making sound decision processes and, as a result, decisions that work over time.

X. ACKNOWLEDGEMENTS

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XI. REFERENCES

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